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P01/7700 0.00-0000954.8

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference — 459GB

2. Patent application number *(The Patent Office will fill in this part)* — 0000954.8

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Renishaw plc
New Mills
Wotton-under-Edge
Gloucestershire, GL12 8JR

Patents ADP number *(if you know it)* — 2691002

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

4. Title of the invention — Spectroscopic Probe

5. Name of your agent *(if you have one)* — J T Jackson et al

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Renishaw plc, Patent Department
New Mills,
Wotton-under-Edge
Gloucestershire
GL12 8JR

Patents ADP number *(if you know it)* — 6446298001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
-	-	-

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*
-	-

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

SPECTROSCOPIC PROBE

This invention relates to a probe for use in spectroscopy, for example Raman or fluorescence spectroscopy. It also relates to a method of manufacturing a component of such a probe.

Probes for spectroscopic use are known from, for example, US Patents Nos. 5,112,127 (Carrabba et al) and 5,377,004 (Owen et al).

The probes shown in those patents are supplied with laser light via an optical fibre, and the laser light is focused by a lens onto a sample. Resulting scattered light, e.g. Raman scattered light or fluorescence at different wavelengths from the laser, is collected by the lens and fed to a second optical fibre, which takes it to a spectroscopic device for analysis. In the Carrabba patent, the scattered light is folded out of the path of the illuminating laser beam within the probe by a beamsplitter. The Owen patent describes an inverse arrangement, in which the scattered light passes in a straight line through the beamsplitter. The beamsplitter acts to fold the illuminating laser light into this beam path, towards the sample.

In both the Carrabba and Owen patents, the beamsplitter is a dichroic filter. This has several advantages. Firstly, a dichroic filter reflects and transmits the various wavelengths more efficiently than a conventional beamsplitter. Secondly, it rejects Raman scattering or fluorescence caused by the interaction of the intense laser light with the glass of the optical fibre which delivers the laser light, passing only a monochromatic laser

wavelength to the sample. Thirdly, it removes much of the laser wavelength which is back-scattered by the sample along with the desired Raman or other scattered wavelengths. Thus, the desired scattered wavelengths do not become confused in the return optical fibre with Raman scattering or fluorescence induced in the optical fibre by the laser wavelength, which as received from the sample is many times more intense than the desired signals. It also makes it easier to separate the desired wavelengths from the laser wavelength in the spectroscopic apparatus.

In some applications, it is desirable to miniaturise such a probe. One example is where the probe is to be incorporated in an endoscope for medical examinations, where a maximum diameter of 2mm or less may be desirable. The probes described in the Carrabba and Owen patents comprise numerous discrete components which must be assembled and aligned, making it impossible to achieve such miniaturisation.

The present invention, at least in preferred embodiments, seeks to provide a probe having fewer discrete components.

One aspect of the present invention provides a component for a spectroscopic probe, comprising a block of transparent material, having two opposed angled faces arranged for reflection of light from one to the other within the block. Preferably at least one of said angled faces has a reflecting or partially reflecting coating, e.g. a dichroic filter coating which reflects light of a first wavelength (or range of wavelengths) and transmits light of a second wavelength (or range of wavelengths).

In a second aspect, the present invention provides a

spectroscopic probe comprising such a component.

In a third aspect, the invention provides a method of making a component for a spectroscopic probe, comprising the steps of taking a sheet of transparent material, coating at least one face of the sheet of transparent material with a reflecting or partially reflecting coating, e.g. a dichroic filter coating, and cutting said component from the sheet with a cut which is at an angle to said face, thereby producing an angled face with said coating in the resulting component.

The other angled face of the component (opposing the angled face with the dichroic coating) may be coated with a reflecting material, e.g. aluminium. Likewise, in the method according to the invention, the face of the sheet of transparent material which opposes the face with the dichroic coating may be coated with a reflecting material such as aluminium.

Preferred embodiments of the present invention will now be described by way of example, with reference to the accompanying drawings, wherein:

Fig 1 is a side view of a spectroscopic probe,

Fig 2 is an isometric view of part of a sheet of transparent material for use in a method of manufacturing a component of the probe,

Fig 3 shows a portion cut from the sheet of Fig 2, and

Fig 4 shows a component of a spectroscopic probe cut from the portion of Fig 3.

Fig 1 shows an embodiment of the present invention in which the component 10 is a monolithic substantially cuboid-shaped block of transparent material. An angled face 12A

of the block 10 is coated with dielectric layers forming a notch or edge dichroic filter. An opposing angled face 12B is coated with a reflective layer, for example of aluminium. It could instead have the same coating as the face 12A.

A graded index (GRIN) lens 20 couples an incoming laser beam 30 from an optical fibre 31 into the block 10. The laser beam 30 contains not only the laser wavelength but also scattered light (including Raman scattered light) from the passage of the beam through the optical fibre. It is reflected by the reflective coating 12B towards the face 12A.

The beam is then reflected by the dichroic filter layer on the face 12A. In the case of a notch filter, this acts to monochromate the beam by reflecting the laser wavelength and transmitting all other wavelengths. In the case of an edge filter, it removes scattered light on the Stokes side of the laser line.

If desired, one end of the GRIN lens 20 may be coated with dielectric layers forming a band pass filter, to monochromate the beam further.

The resulting monochromatic beam 32 is then focused on the sample to be analysed by a GRIN lens 22. Back-scattered light is collected by the lens 22 and passes back to the dichroic surface 12A which reflects the exciting laser wavelength but transmits the desired Raman or fluorescent scattered light 34 into a GRIN lens 24. The lens 24 couples the scattered light 34 into a second optical fibre 33, which takes it to a remote spectroscopic apparatus for analysis.

The faces 12A,12B are preferably angled at a low angle of incidence to the beams, such as 10°. This gives good performance with polarised light, and efficient separation of the laser wavelength from the desired Raman or fluorescent scattered light. However, other angles such as 45° are possible.

Fig 2 shows a part 38 of a sheet of transparent material for use in manufacturing the probe component 10. The lower face 39A is coated with the dielectric layers forming the dichroic filter and the upper face 39B is coated with the reflective layer.

Broken lines 40 and 41 represent the directions along which the sheet 38 is cut using a diamond saw. The lines 41 do not run normal to the plane of the sheet but rather at an angle (e.g. 10°) as indicated by the broken lines 42.

Fig 3 illustrates (side-on) one of a plurality of portions 45 of the transparent sheet 38 after cutting along the lines 40.

Fig 4 shows the finished block 10 as in Fig 1. The portions 45 are cut along the lines 41,42 to produce a plurality of individual blocks. Prism-shaped sections 50A and 50B are then removed from the blocks, e.g. by polishing, such that the polished faces are perpendicular to the long edges 11A and 11B of the block. The coatings 39A,39B remain only on the faces 12A,12B as required.

The GRIN lenses 20,22,24 are then bonded to the block 10, e.g. with a cement of suitable optical quality.

As described above, blocks 10 have been produced by cutting

the sheet 38 first along the lines 40, then along the lines 41,42. Of course, it is possible instead to cut first along the lines 41,42 and then along the lines 40.

Using the above method, we have successfully produced spectroscopic probes with diameters of 2mm and less, suitable for use in an endoscope.

The use of GRIN lenses 20,22,24 is not essential. Conventional lenses (or compound groups of lenses) may be substituted.

One advantage of the probe described is that it can act confocally. The aperture of the fibre 33 acts in a similar manner to a confocal pinhole, so that only light from one focal plane of the sample is accepted and light from other planes is rejected. This gives depth selectivity.

It is possible to replace the single fibre 33 with a bundle of optical fibres, all receiving light via the lens 24. One central fibre of this bundle then receives light confocally, scattered from the focused spot produced by the input fibre 31 and the lenses 20,22. Other fibres receive light from other planes in the sample.

Another possibility is to provide a bundle of input fibres, in place of the single fibre 31. Each may then produce an individual focused spot in different positions in the focal plane of the sample. A corresponding fibre in the output bundle receives light confocally from each of the individual spots. It is then possible to form a two-dimensional confocal image of the focal plane of the sample.

A further possibility is to bundle a plurality of probes according to Fig 1 together, in a single endoscopic instrument. Again, this may be arranged to produce a two-dimensional image of the sample, which may be confocal. Or each probe may point in a different direction, e.g. in a hemi-spherical arrangement, to give a view over a wider area.

The miniature probes described may be used in numerous applications where conventional spectroscopic probes would be too large. In addition to endoscopes for in vivo medical and veterinary examinations, they can for example be used in boroscopes for examinations within working machinery and engines.

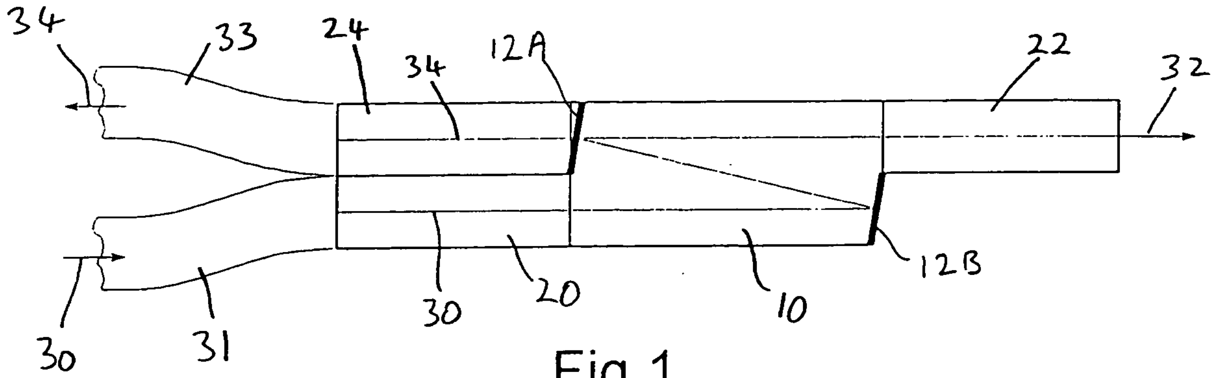


Fig 1

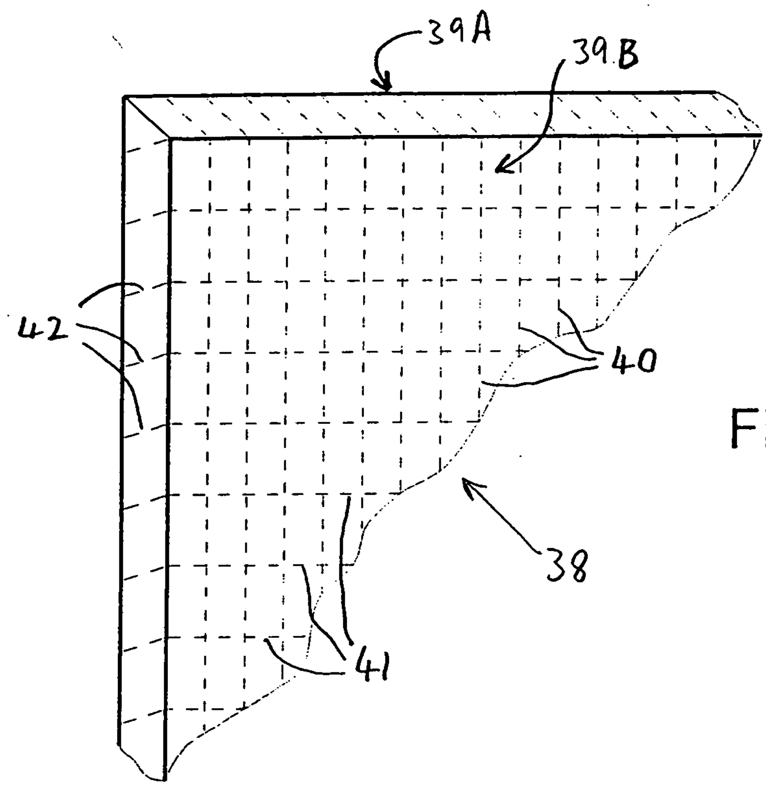
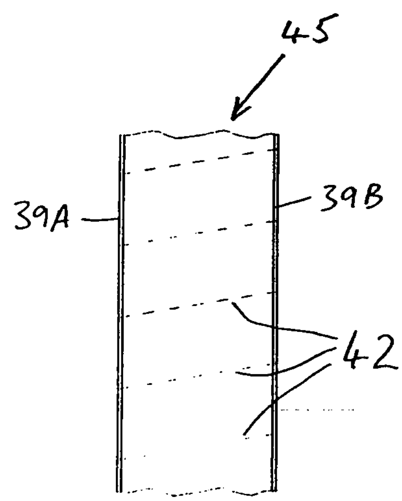


Fig 2



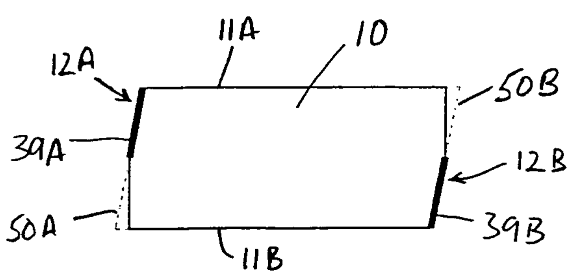


Fig 4

Fig 3